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Leading Innovation >>>

# **EUVL Regional Review of Japan**

**June 17, 2015**

**Takayuki UCHIYAMA**

**TOSHIBA Corporation**

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- **Introduction of EIDEC activity**

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# **Update of One Hundred Watt HVM LPP-EUV Source**

2015 International Workshop on EUV Lithography

Makena Beach & Golf Resort, Maui, Hawaii, USA June 15-19, 2015

Dr. Hakaru Mizoguchi  
CTO & Executive Vice President  
Gigaphoton Inc.

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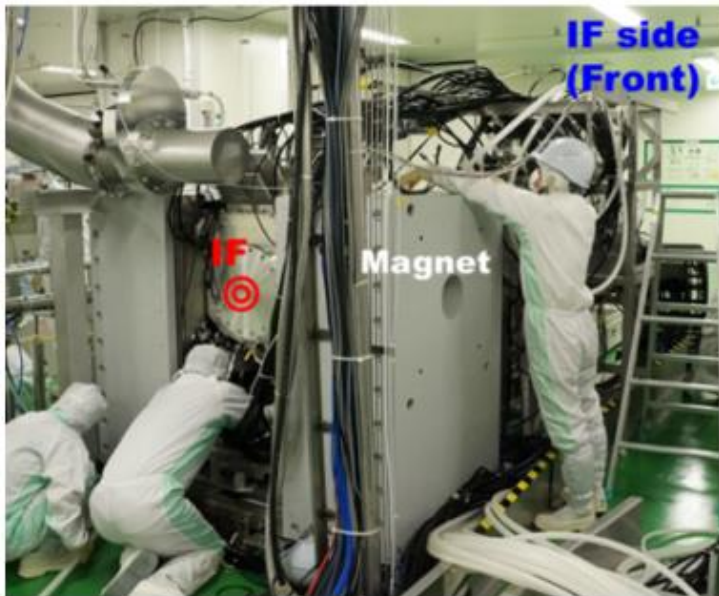
DOC#: ED15L-020



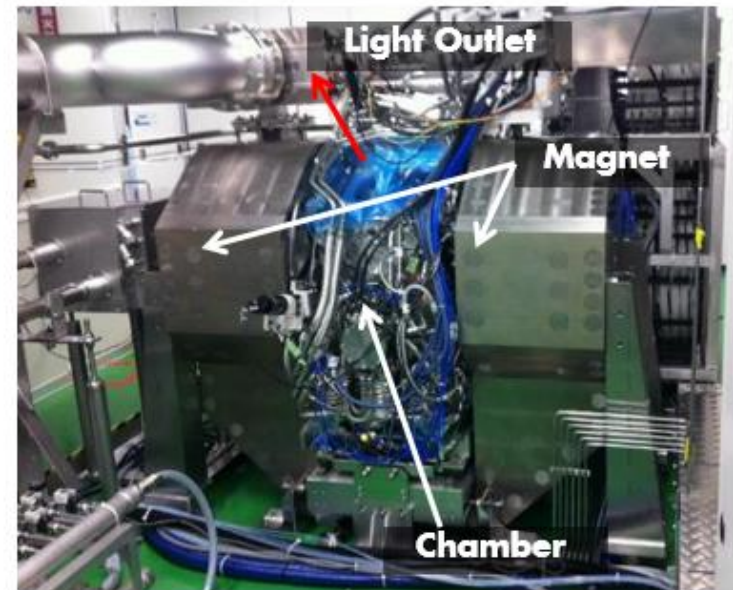
# Gigaphoton's High Power EUV Light Source

Prototype high power EUV light source is in operation

Proto 1 Exposure & Mitigation test



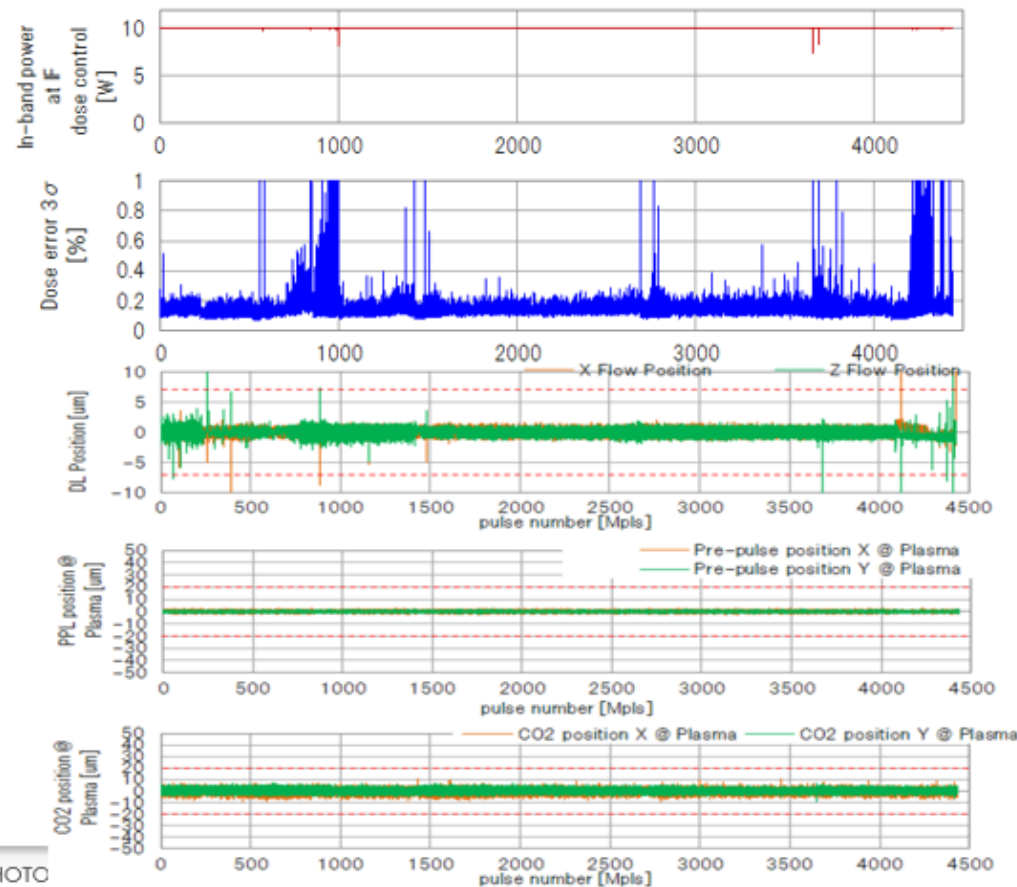
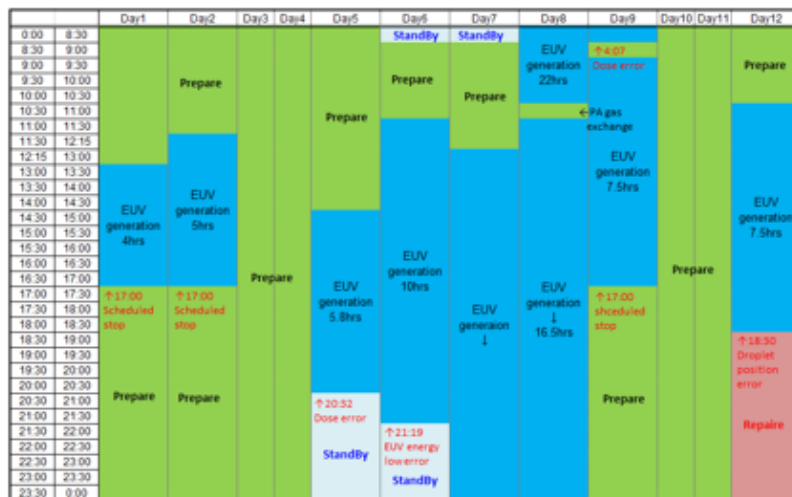
Proto 2 High power Experiment



# Proto#1 77 hours EUV emission

Updated

- Average power 10W with dose control, 77 hours EUV emission was achieved by Proto#1 (Total operation time is 261 hours)
- Total pulse number is 4.4Bpls.
- Dose stability 3 sigma: Typically < 0.3%



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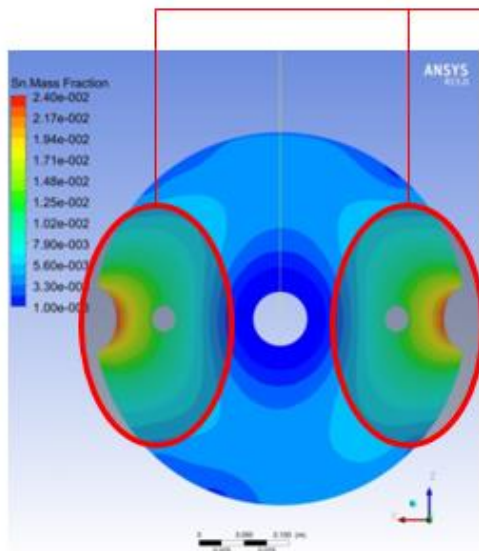
## Resolution Progress:

Updated

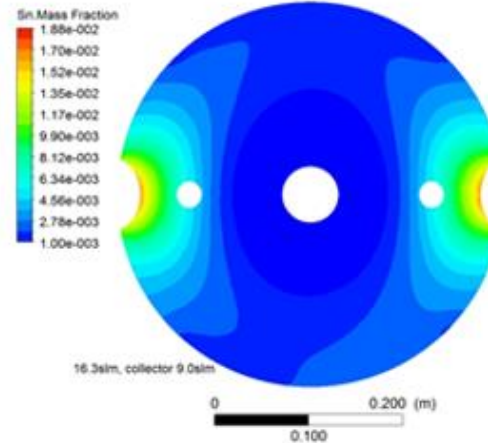
## Tin back-diffusion from the ion catcher

Improvement of back-diffusion from the ion catcher is very clear

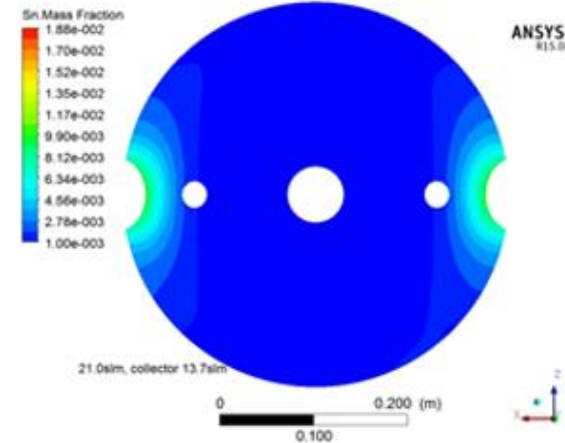
unwanted tin (Sn) debris



Oct. 2014



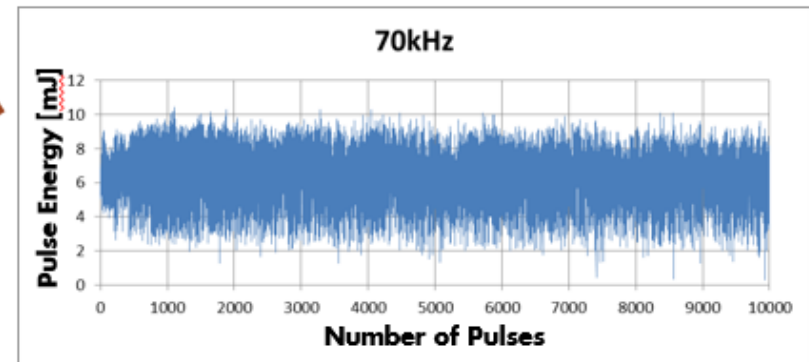
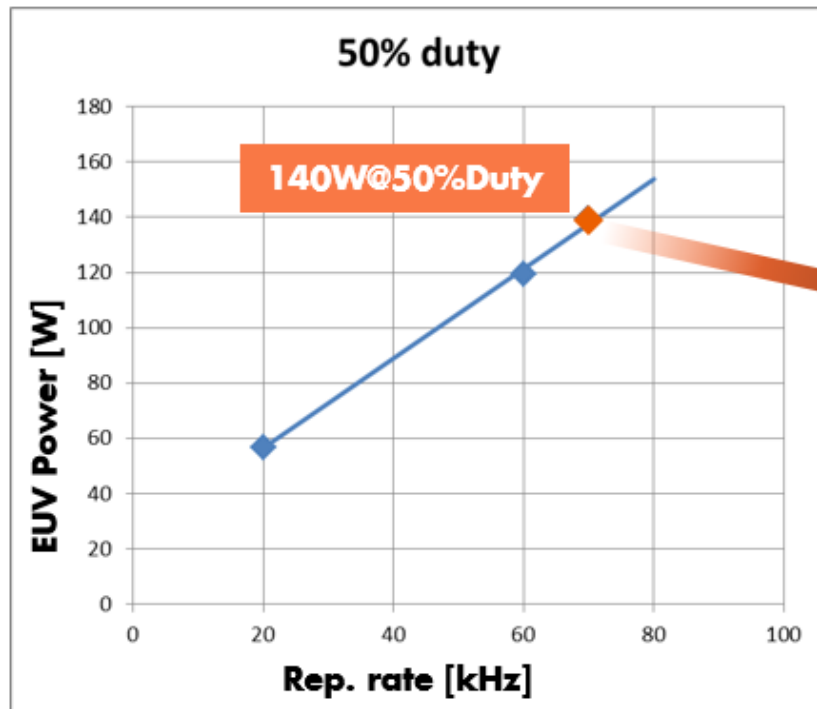
Nov. 2014



Present (Testing)

# Proto #2 EUV Power Data

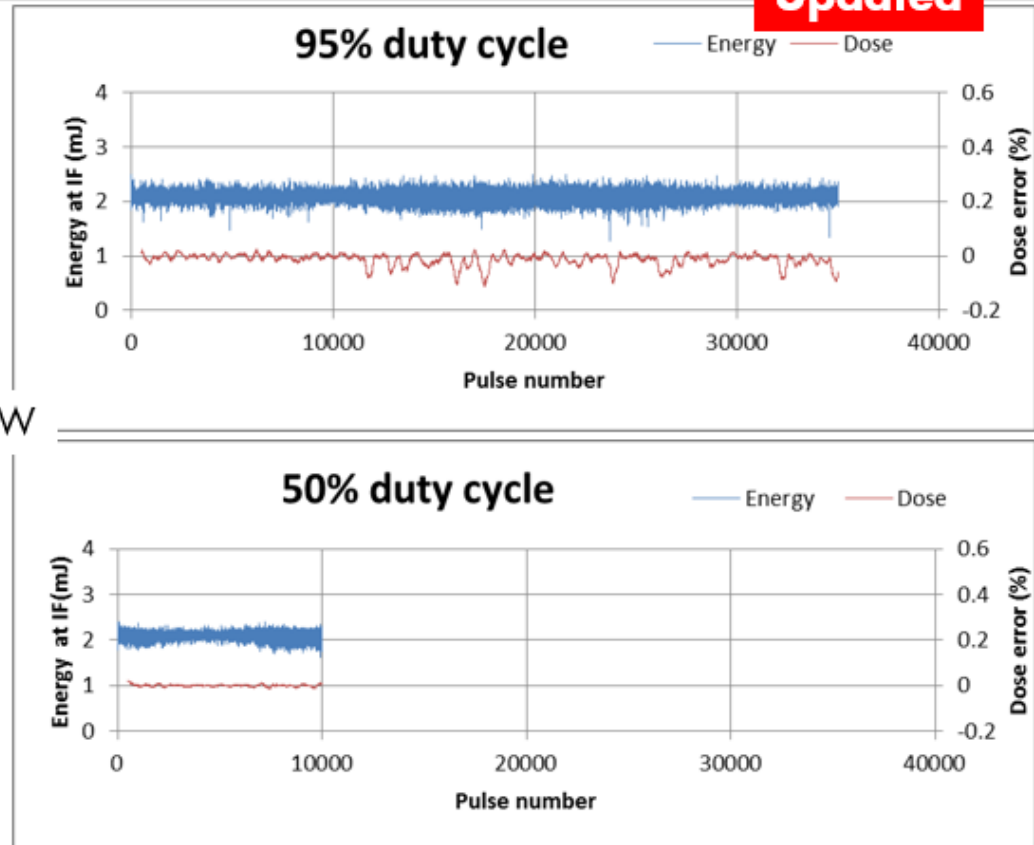
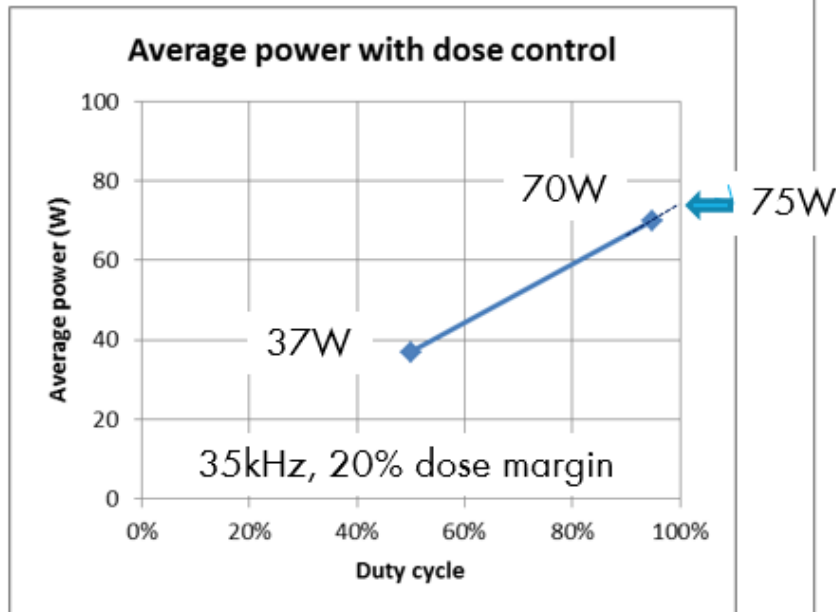
Champion Data: 140W EUV in burst power with 70kHz, 50% duty cycle



## Proto#2: High duty cycle operation with dose control

Updated

- Dose control capability up to 95% duty cycle with 20% dose margin was confirmed in proto#2 system at 75W in burst level operation.



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June, 5, 2015

DOC#: ED15L-020



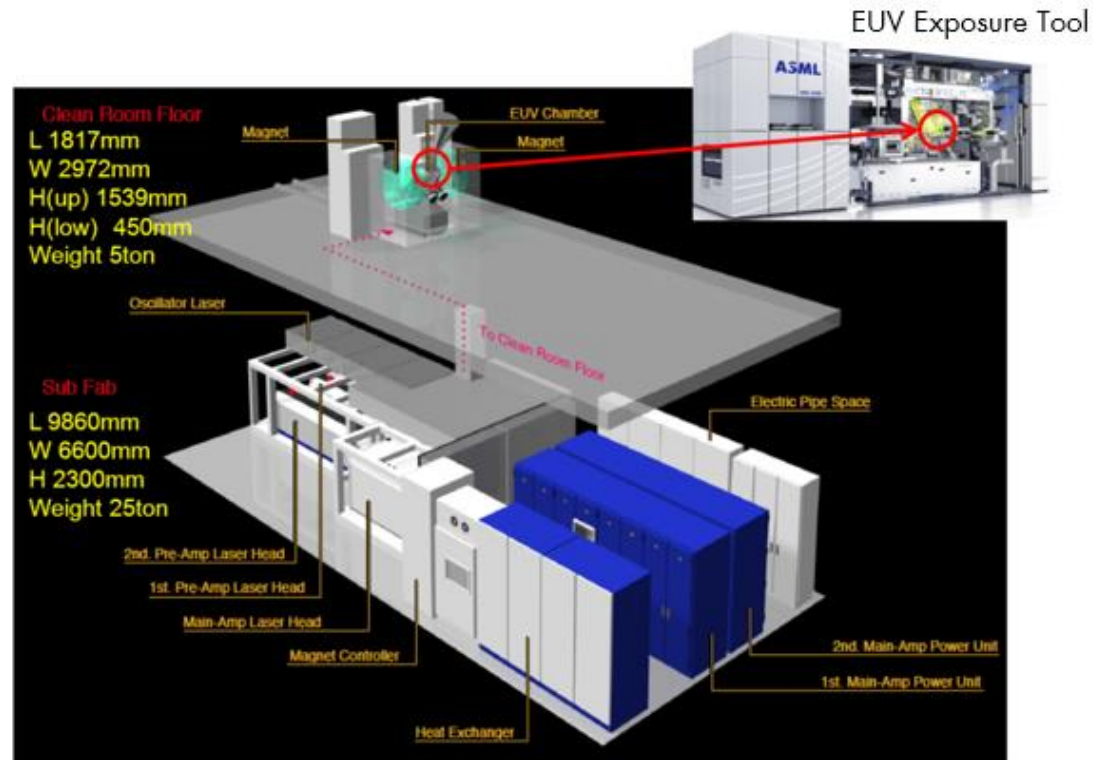
# Pilot #1 EUV Light Source for HVM

## Layout of 250W EUV Light Source

### First HVM EUV Source

- 250W EUV source

| Operational specification (Target) |                   |                 | HVM Source             |
|------------------------------------|-------------------|-----------------|------------------------|
| Performance                        | EUV Power         |                 | > 250W                 |
|                                    | CE                |                 | > 4.0 %                |
|                                    | Pulse rate        |                 | 100kHz                 |
|                                    | Availability      |                 | > 75%                  |
| Technology                         | Droplet generator | Droplet size    | < 20mm                 |
|                                    | CO2 laser         | Power           | > 20kW                 |
|                                    | Pre-pulse laser   | Pulse duration  | psec                   |
|                                    | Debris mitigation | Magnet, Etching | > 15 days (>1500 Mpls) |



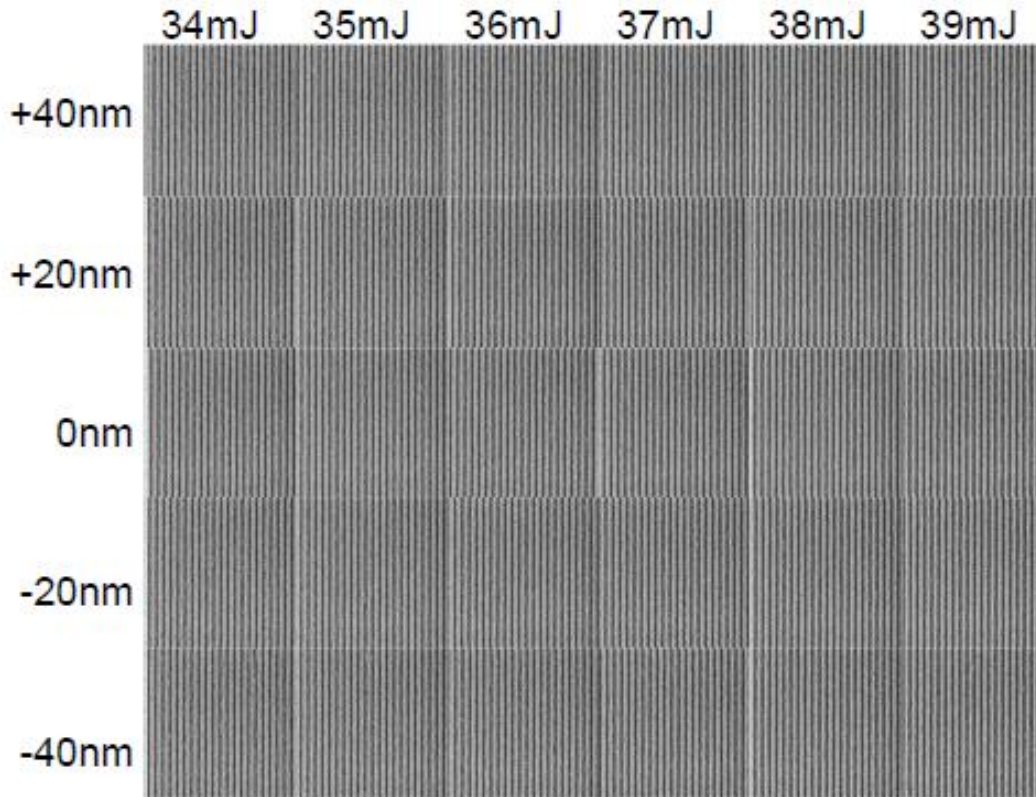
## Summary

- Progress of Proto #1 unit;
  - » Further improvement of “Magnetic debris mitigation”
    - Simulation expect further improvement of back-diffusion.
  - » New 77hrs 10W operation data without maintenance was reported.
- Progress of Proto #2 unit;
  - » Driver CO<sub>2</sub> Laser system achieved 20kW with pre-amplifier by Mitsubishi Electric
  - » Maximum Power Champion data: 140W (CE3.7%) in burst at 70kHz, 50% duty.
  - » 120-100W power in burst, 50% duty, (60-50W average) for 120min.
  - » Reported New Data
    - Dose control capability is proved experimentally, until 95% at 75W in burst level.
  - » Next step is higher average power operations during more than 24 hours.
- Pilot #1 is under construction;
  - » Design of system is almost fixed. Most of parts is already ordered.
  - » Construction will finish on Q3 2015. First data will be expected on Q4 2015.

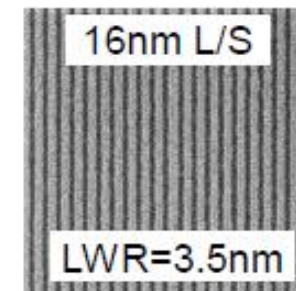
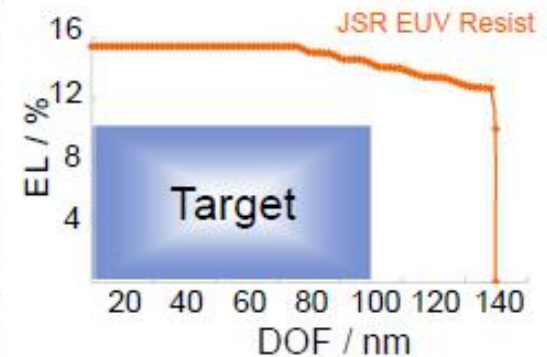
JSR Ref No. J00019982  
JSR  
LABORATORY

## JSR EUV Resist for 16nm HP

### 16nm L/S ED window



Exposure Courtesy of ASML and imec



[Process Conditions]

Substrate: Organic BARC

Resist FT: 35nm

Exposure: NXE:3300B, NA0.33, Dipole45X

✓ JSR EUV photoresist showed  
certain process window at 16nmHP.

May 25, 2015 No.151451



## JSR High Resolution EUV Resist

on NXE3300

Dipole90X

16nm LS

LWR=5.2nm  
EL >15%

39.2mJ/cm<sup>2</sup>

on NXE3300

Dipole45X

15nm LS

40.4mJ/cm<sup>2</sup>

14nm LS

36.8mJ/cm<sup>2</sup>

13nm LS

38.6mJ/cm<sup>2</sup>

- ✓ 13nm HP (NXE3300) and 12nm HP (PSI) resolution was achieved by JSR EUV photoresist.



on PSI

12nm LS

40.5mJ/cm<sup>2</sup>

Resolve

11nm LS

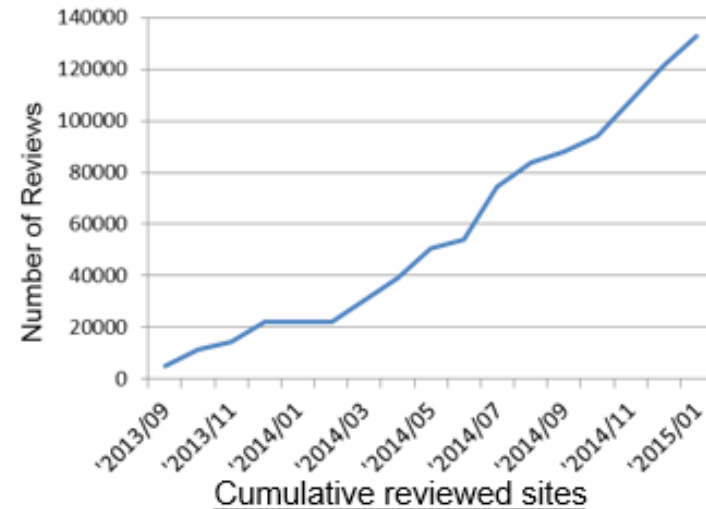
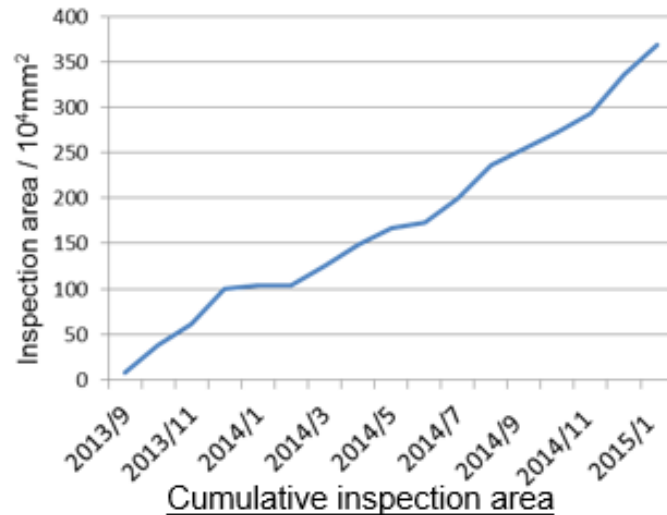
33.6mJ/cm<sup>2</sup>

Pattern collapse

May 25, 2015 No.151451

## Actinic Blank Inspection Tool

Blank Inspection Technology (BI)

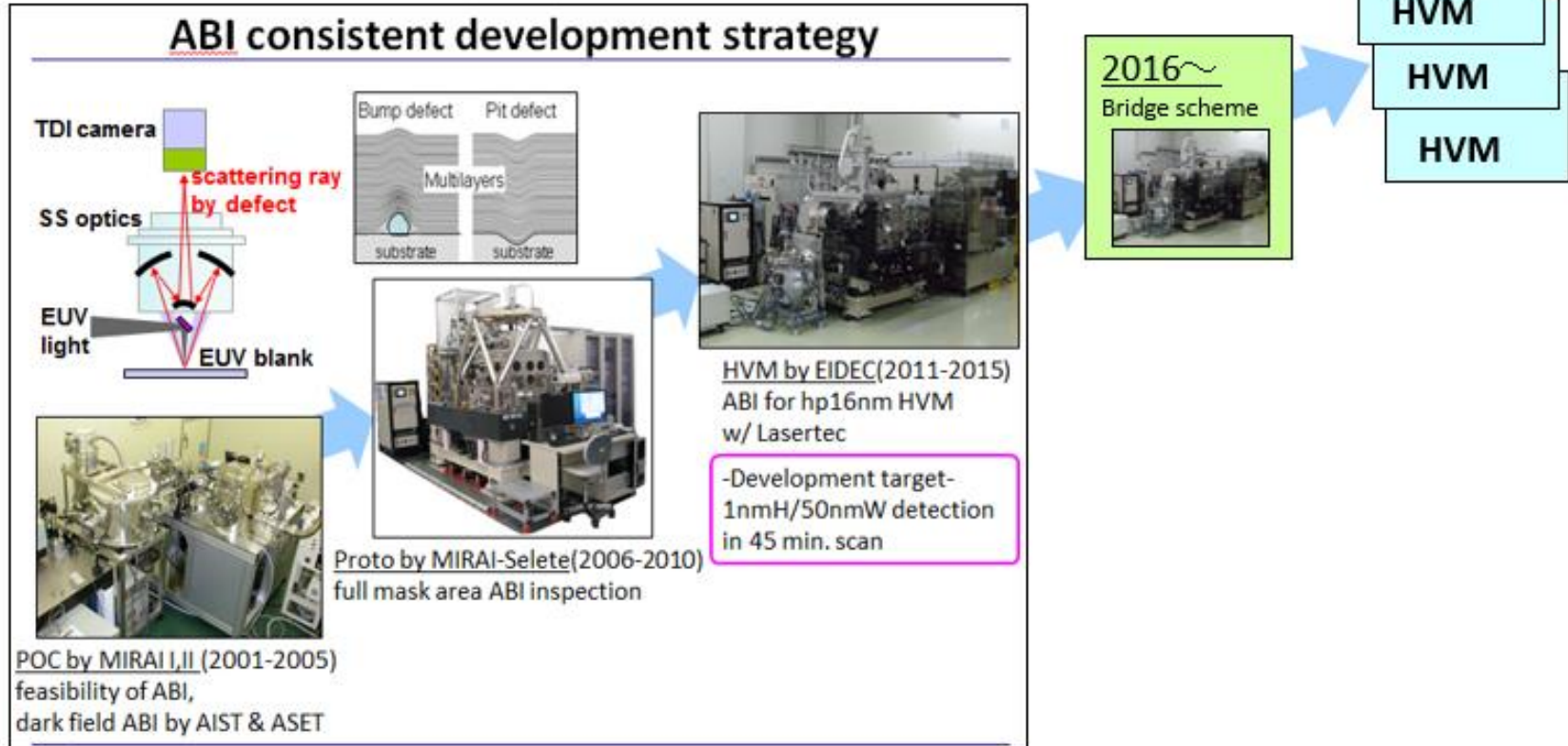


### ABI tool development update

- ✓ Developing ABI tool continuously inspects blanks and reviews defects to improve tool capability and blanks quality
- ✓ ABI tool is being refined to improve (1) detection capability, (2) defect location accuracy, and (3) tool productivity (MTBF, MTTR, CoO, installing additional functions to enhance the tool value of ABI)

## Blank Inspection Technology (BI)

## ABI Tool Utilization Scheme





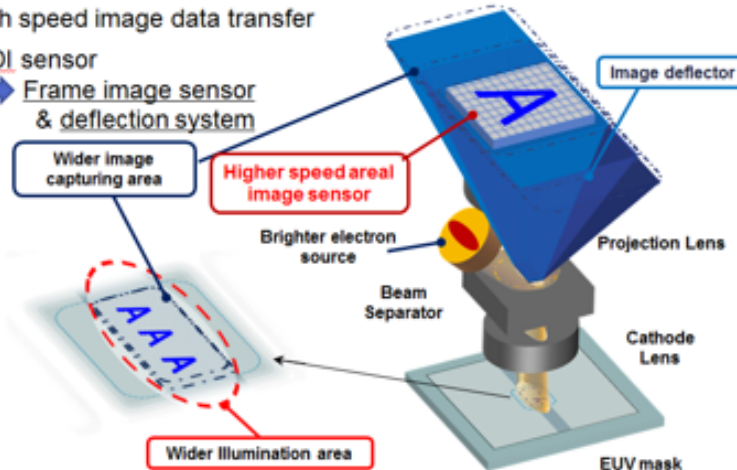
## Patterned mask Inspection (PI)

### High speed image acquisition

### High speed image data transfer

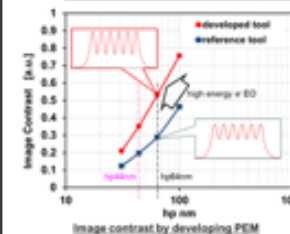
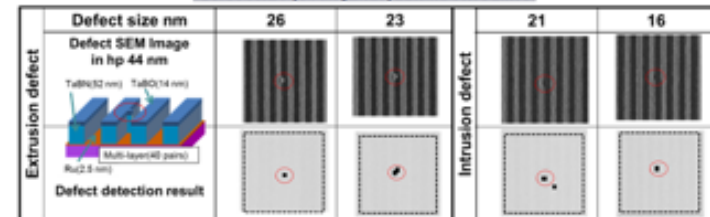
### TDI sensor

#### Frame image sensor & deflection system



### Detection capability in hp44nm dense lines

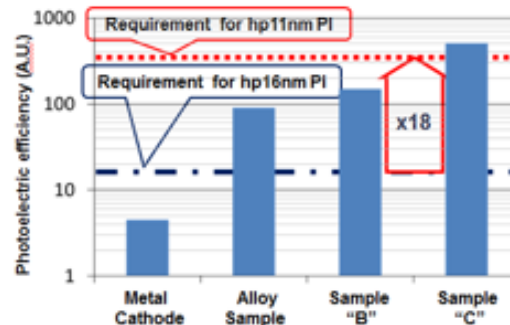
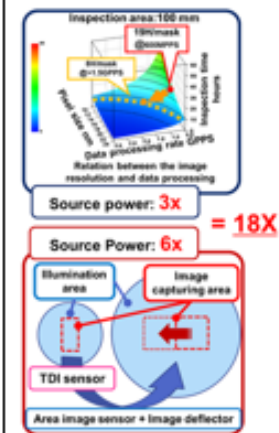
#### Detection capability in hp44nm dense lines



#### 2/3 image contrast in hp44nm vs. hp64nm

- Developing image processing technique captures down to 16nm sized defect,
- Further image correction technique is required to achieve the hp11nm specification; 13nm sized defect detection w/o noise

### Bright electron source



High speed image processing (3x)  
x Wide area illumination (6x) = 18x  
electrons are managed by  
ultra high efficiency electron source

- PI tool is being modified to enhance the advantage by PEM, the higher throughput,
- Improving image processing technique enables to achieve almost requirement for hp11nm defect detection,

## EUV Resist Material Research (ERM)

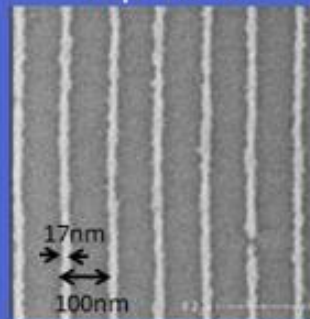
### EIDEC Standard Metal EUV Resist (ESMR)



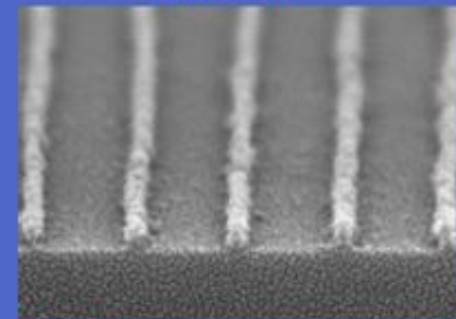
EIDEC Standard Metal EUV Resist (ESMR) achieved ultra high sensitivity ( $1.5 \text{ mJ/cm}^2$  : equivalent in EUV lithography) at **17nm line** (100nm pitch) with EB-lithography tool .

#### 17nm Line

Top-View



X-section



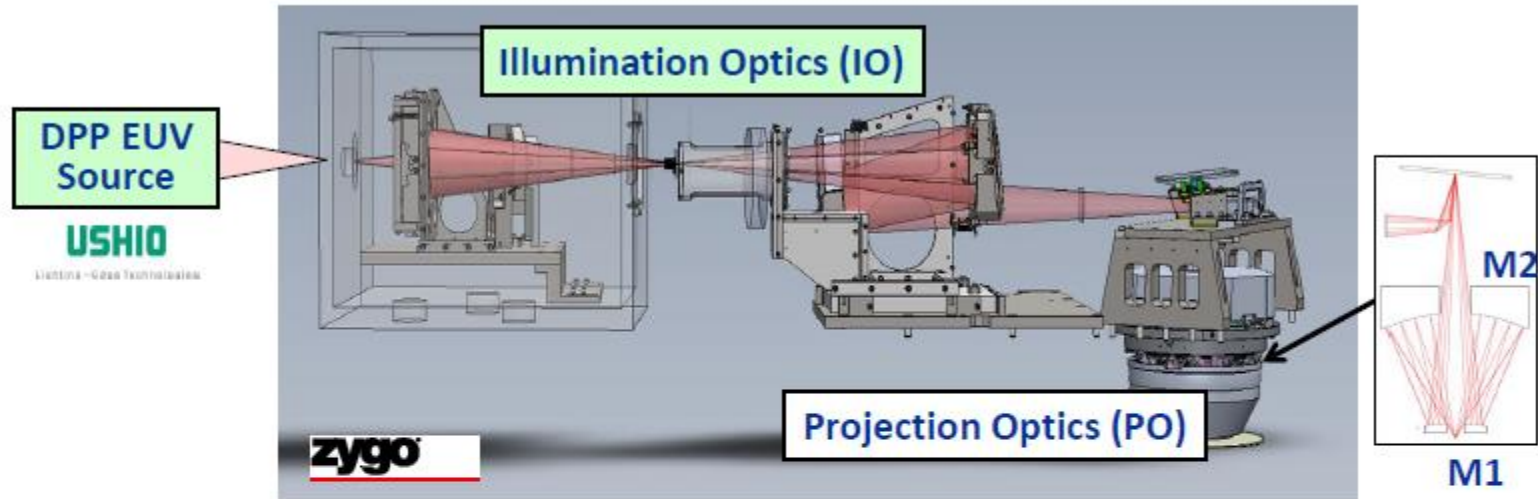
Equivalent to  $\sim 1.5 \text{ mJ/cm}^2$  in EUV lithography

Thickness=50nm, Exposed with EB-lithography tool

#### More detailed investigation of ESMR

- Lithographic performance using EUV exposure
- Fundamental study of
  - Structure in the resist film
  - Reaction mechanisms under exposure
  - Shelf life and post-coating stability
  - Dry etching properties

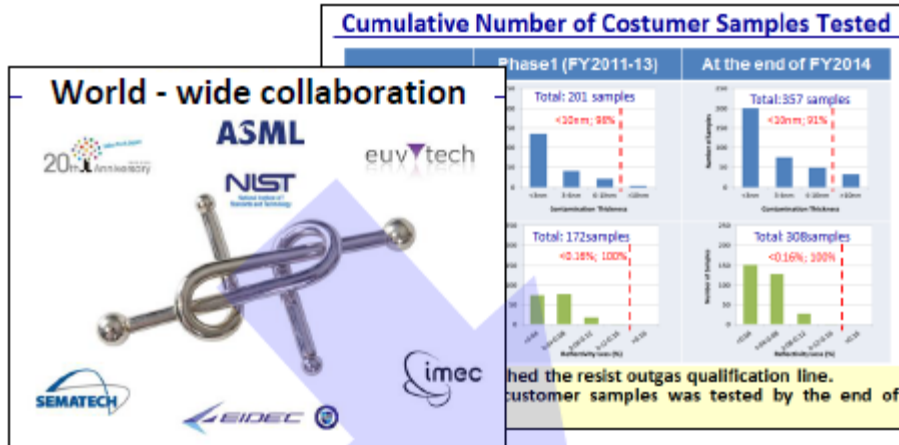
## HSFET (High NA Small Field Exposure Tool)



**HSFET will be in operation  
in FY2015/3Q**



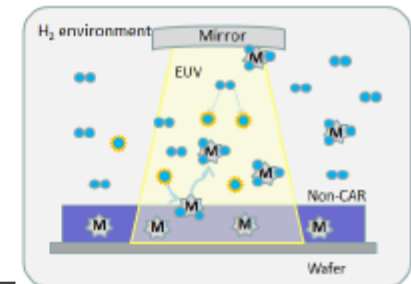
## EUV Resist Outgassing Control (ERC)



### Current Status of Resist Outgas Testing

**ASML announced the relaxation of resist outgassing spec at the end of Feb. 2015.**

- Traditional Chemically Amplified Resist (CAR)
  - No outgas spec for both cleanable and non-cleanable contamination
  - Monitoring during 2015
- Non-CAR (High Sensitivity Resist)
  - Limited litho testing in EUV scanner
  - Proposal / request to outgas testers for resist outgassing research
    - ✓ EUV light for both WS and wafer
    - ✓ Hydrogen environment
    - ✓ Variable parameters



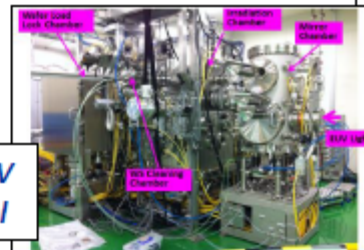
### ERC Research Plan in 2105

*To improve the rulebook for resist outgassing control for Non-CAR*

- Accurate outgassing measurement
  - ✓ Intensive investigation on Non-CAR outgas characterization in H<sub>2</sub>
- Proper outgassing prediction
  - ✓ Enhancement of semi-empirical modeling for Non-CAR
- Verification for HVM
  - ✓ Establishment of outgas testing with high power and pulsed light

Rulebook Improved

**High Power EUV Irradiation Tool**



# Acknowledgment

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The author would like to thank Gigaphoton, JSR and EIDEC.



